Effects of dental implants on hard and soft tissues

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Chapter 5

Treatment outcome of two adjacent implant crowns in the aesthetic zone; a retrospective study

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Abstract

Aim The purpose of this study was to evaluate clinical and radiographic parameters and the aesthetic outcome of two adjacent implant crowns and the surrounding peri-implant mucosa in the maxillary aesthetic zone.

Materials and Methods Ten patients were treated with two adjacent implants in the anterior maxillary zone according to the same protocol. Only patients that had been subjected to a separate augmentation procedure with autogenous bone were included in this study. The following parameters were analysed: implant survival, marginal bone level, vertical distance between the contact point and the bone crest, papilla index, probing depth, aesthetic index and patients' satisfaction.

Results Implant survival was 100 %. The inter-implant bone crest level was positioned significantly more apically than the bone crest level between an implant and its neighbouring tooth. In addition, in only one out of 10 cases a complete fill of the interproximal space was observed between two adjacent implant crowns, whereas the papilla between the implant and its neighbouring teeth was present in 70 percent of the cases. Furthermore, patients rated the aesthetic outcome of their implant crowns and the surrounding mucosa in all cases as at least 'acceptable', while the professionals' judgement as scored by the implant crown aesthetic index resulted in 6 'acceptable' and 4 'unacceptable' outcomes.

Conclusions It was concluded that, although many patients were satisfied with the aesthetic result, it is difficult to establish an acceptable aesthetic result of two adjacent implant crowns in the aesthetic zone in cases that needed a separate augmentation procedure according to the contemporary standards of dental professionals.

Chapter 5

Introduction

The criteria for success for implants in the aesthetic zone involve the establishment of a soft tissue contour with an intact interproximal papilla and a gingival outline that is harmonious with the gingival silhouette of the adjacent healthy dentition (Choquet et al., 2001). Despite the surgical techniques developed, creating a predictable papilla around a single-tooth implant, and to an even higher level between two adjacent implants, remains a complex challenge.

The presence of interproximal papillae next to single tooth implants is determined predominantly by the marginal bone level of the neighbouring tooth (Kan et al., 2003; Grunder et al., 2005). Unlike around single-tooth implants, an inter-implant papilla is not supported by the marginal bone level of a neighbouring tooth. In addition, in case of two missing adjacent teeth, the bone condition is in most cases compromised; due to resorption the characteristic interdental bone peak is missing. Even more, it is not uncommon that deficiencies of the horizontal or vertical hard tissues are to the extent that an augmentation procedure is required to enable reliable implant placement at a location favourable for prosthodontic rehabilitation. Furthermore, both the distance between two adjacent implants and the distance between the inter-implant bone level and the contact point of the implant crowns are thought to play an important role in the regeneration of an inter-implant papilla (Tarnow et al., 2000; Cardaropoli et al., 2003). In general, the placement of two adjacent implant crowns is still considered a treatment of which it is difficult to establish a predictable harmonious result.

Although it is vital to evaluate the peri-implant hard and soft tissues, at the long run the overall satisfaction of the patient is the primary outcome parameter. Several studies reported about the patient satisfaction regarding implant crowns (Levi et al., 2003; Vermylen et al., 2003). Few other studies compared the satisfaction of the patient with the opinion of the dental professional (Chang et al., 1999; Palmer et al., 2007). All these studies reported high levels of the patients' satisfaction. If the professionals' opinion was also evaluated, it was always less positive than the patients' opinion. There are no studies yet reported in the literature, dealing with the aesthetic outcome of two adjacent implant crowns, judged by professionals and by the patient self. Therefore, the aim of this study was to evaluate clinical and radiographic parameters and the patients' and the professionals' opinion of two adjacent implant crowns in the maxillary aesthetic zone that had been reconstructed with autogenous bone before implant placement.

Material and Methods

The patients selected for this study were referred to the department of Oral and Maxillofacial Surgery of the University Medical Center Groningen for implant therapy between 1997 and 2004. Patients were included if (1) they had been treated with two adjacent implant crowns in the anterior aesthetic maxillary zone (first bicuspid, cuspid and incisors), (2) they had undergone multiple surgeries including a separate augmentation phase with autogenous bone, (3) the treatment had been entirely (surgery and prosthetics) performed at the department mentioned above, and (4) the final restoration had been in place for at least one year. Ten patients met the inclusion criteria and agreed to participate in the study. Patient characteristics are listed in Table 1. As is apparent from the inclusion criteria, all patients needed a separate augmentation surgery because of an insufficient bone volume for placement of an implant with sufficient initial stability and in a prosthodontic perspective most favourable position.

In all cases bone grafts were harvested from the chin region under local anaesthesia. Three months after augmentation, two turned titanium self tapping, Brånemark-implants (Nobel Biocare AB, Göteborg, Sweden) had been inserted in a two-stage procedure. After six months implant crowns were constructed. The restorations consisted of a titanium custom made abutment and a porcelain restoration (Procera; Nobel Biocare AB, Göteborg, Sweden). All patients were subjected to a strict oral hygiene programme. Special care was given to the interproximal cleansing. The patients were instructed to use dental floss in order to preserve the interproximal papilla.

Table 1. Characteristics of the study group.

Number of participants	10
Age (years; mean / range)	35.1 / 21-55
Prosthetic loading time (years; mean / range)	4.33 / 1.6-8.5
Augmentation prior to implantation (yes / no)	10 / 10
Gender (male / female)	8 / 2
Tooth gap position (central + central / central+ lateral)	7 / 3

Chapter 5

Clinical outcome measures

The soft tissues around the adjacent implants and their neighbouring teeth were clinically examined by assessing the following parameters: (1) implant survival, (2) the gingiva-index (Löe & Sillness, 1963), (3) the plaque-index (Mombelli et al., 1987), (4) the bleeding index (Mombelli et al., 1987), (5) the papilla index (Jemt, 1997) and (6) the pocket probing depth: the depth of the sulcus was measured to the nearest millimetre at three locations around the implants and the neighbouring teeth (at the side of the neighbouring teeth, mediobuccally and at the side of the adjacent implant). The distance from the gingival margin to the bottom of the sulcus pocket was scored as the 'pocket probing depth'

Radiographic outcome measures

During the evaluation visit a digital periapical radiograph was taken using the paralleling technique (Benkow, 1957). A computer-assisted calibration was carried out in the horizontal plane and, if necessary, in the vertical plane for each radiograph. In the horizontal plane the known dimension of the diameter of the implant was used to calibrate the radiograph. When the implant was slightly angulated, the radiograph was also calibrated in the vertical plane by using the known distance of several threads as calibration. This calibration ensured a correct measurement (Sewerin, 1990). The radiographs were analysed using computer software to perform linear measurements on the digital radiographs. The measurements were performed twice by the same observer with a 2-week time interval. The mean of these 2 measurements was used for analysis of the data (Meijndert, 2004). Measurements were excluded if one a landmarks to be determined could not be confidently identified. In the vertical plane, the following linear measurements were assessed to the nearest 0.1 mm (Figure. 1): (1) the interface of the implant and the abutment was used as a reference line from which all distances were measured (line a), (2) the first bone to implant level: the vertical distance between a and the first bone to implant level, measured at the implant side facing the adjacent implant (MBI_i) and at the implant side facing the neighbouring tooth (MBI_t), (3) the bone level of the neighbouring tooth: the vertical distance between a and the first bone to tooth level (MBT), (4) the bone crest level: the vertical distance between a and the most coronal bone peak of the inter-implant bone crest (BC_{i-i}) and the most coronal bone peek of the bone crest between the implant and its adjacent tooth (BC_{i-t}), (5) the contact point: the vertical distance between a and the most apical contact point of

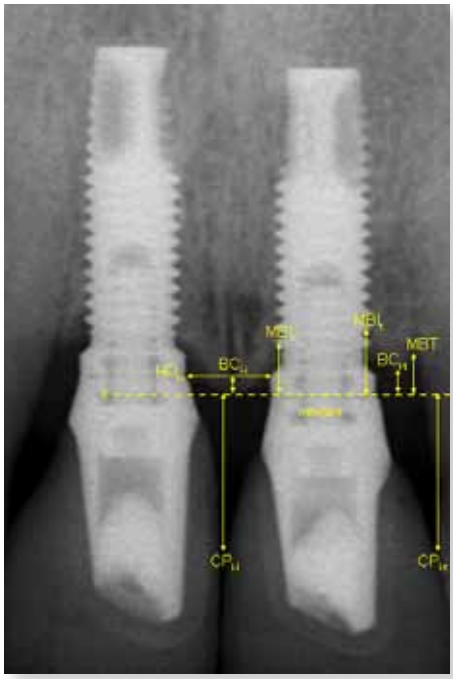

Figure 1.

Illustration of the linear measurements on radiographs in the vertical plane: the marginal bone levels (MBI_i and MBI_t), the marginal bone level of the neighbouring tooth (MBT), the inter-implant bone crest level (BC_{i-i}) and the bone crest level between the implant and its adjacent tooth (BC_{i-t}), the contact point between the implant crowns (CP_{i-i}) and between the implant crown and the crown of its adjacent tooth (CP_{i-t}). Measurements in the horizontal plane: inter-implant distance (HD_{i-i}). See 'Material and Methods' for explanation.

the implant crowns (CP_{i-i}) and of the implant-supported restoration and the restoration of the adjacent tooth (CP_{i-t}) and (6) contact point – bone crest level: the distance between the most coronal bone level of the bone crest and the contact point is calculated by adding up CP_{i-i} and BC_{i-i} (C_{i-i}) and by adding up CP_{i-t} and BC_{i-t} (C_{i-t}).

In the horizontal plane the inter-implant distance: the distance between the two adjacent was measured at height of the implant neck of the two adjacent implants (HD_{i-i}).

Implant crown aesthetic index

Aesthetic outcome by the professional was a using the Implant Crown Aesthetic Index as described by Meijer et al (2005). In this index nine items are judged, which have an influence on the aesthetic result. The items are based on the anatomic form, colour and surface characteristics of the restoration and on the anatomic form, colour and surface characteristics of the peri-implant soft tissues. The index was applied to both implants separately. To asses the overall score, the implant with the worst index score was used as score per patient.

Patient satisfaction

A subjective appreciation of the final result of the treatment was assessed with a modified

patient questionnaire of the one used by Meijndert et al. (2007). The questionnaire comprised an overall satisfaction sore (range; 0-10), three questions concerning the implant-supported restoration and three questions concerning the peri-implant mucosa (possible score; 0-4).

Data analysis

Mean values, standard deviations, minimum and maximum were calculated. Differences between implants and teeth concerning plaque index, bleeding index, gingiva index and papilla index were analysed using the Mann-Whitney test. Differences between pocket probing depth around implants and around teeth and radiographic outcomes measures were analysed using independent t-tests. Correlation between overall score of implant restoration aesthetic index (excellent, satisfactory, moderate and poor) and patient satisfaction overall score (range: 0-10) was calculated with the Spearman correlation test. For that purpose the implant with the lowest index score was used as score per patient. Differences between mucosa scores and crown scores among the patients and among the professionals were analysed using independent t-tests. In all statistical tests, a significance level of $\alpha = 0.05$ was chosen.

Results

Implant survival was 100 %. The bleeding tendency was significantly higher around implant crowns than around natural neighbouring teeth ($p<0.05$), while the plaque index showed the opposite ($p<0.05$). In addition, there was a tendency, that the gingiva was more often inflamed around the implants then around the neighbouring teeth (Table 2). The mean pocket probing depth around implants was significantly deeper than around the teeth ($p<0.05$) (Table 3). The inter-implant papilla was present (papilla index score 2 and 3) in one case only, whereas the papilla between the implant and its neighbouring teeth was present in 70 percent of the cases (Table 4).

There was no significant difference between the mean marginal bone level at the proximal sides of the implants facing the neighbouring teeth and the mean marginal bone level at the proximal sides facing the neighbouring implants, 1.8±0.5 mm and 1.9±0.4 mm apical of the microgap, respectively (Table 5). The mean inter-implant bone crest level was situated significantly more apically than the mean bone crest level between an implant and its adjacent tooth, 1.0±0.7 mm apical of the microgap and 0.8±0.8 mm coronal of the microgap, respectively. Furthermore,

Table 2. Frequency distribution of plaque index, bleeding index and gingiva index of implants and neighbouring teeth.

	Plaque Index*		Bleeding Index**		Gingiva Index‡	
Score	**Implants**	**Teeth**	**Implants**	**Teeth**	**Implants**	**Teeth**
0	19	13	4	11	10	16
1	1	6	7	7	10	4
2	0	1	9	2	0	0
3	0	0	0	0	0	0
Total	20	20	20	20	20	20
Significant (p<0.05)			Significant (p<0.05)		Not significant	

* Plaque Index: score 0 = no plaque, score 1 = plaque detected by running a probe, score 2 = plaque can be seen with the naked eye and score 3 = abundance of plaque.
** Bleeding Index: score 0 = no bleeding after probing, score 1 = isolated bleeding spots, score 2 = confluent line of blood and score 3 = heavy or profuse bleeding.
‡ Gingival Index: score 0 = normal gingival/ mucosa around tooth/ implant, score 1 = mild inflammation, score 2 = moderate inflammation and score 3 = severe inflammation.

Table 3. Pocket probing depth values (mm) measured around implants and neighbouring teeth.

	Implant (n=20)		Tooth (n=20)		
Location	Mean (SD)	Range	Mean (SD)	Range	Difference*
Proximal side facing adjacent implant	3.4 (0.9)	2.0 – 5.0	2.5 (0.5)	2.0 – 3.0	p<0.05
Midbuccaly	3.1 (1.0)	2.0 – 5.0	1.8 (0.4)	1.0 – 2.0	p<0.05
Proximal side facing adjacent tooth	3.7 (1.0)	2.0 – 5.0	2.4 (0.6)	1.0 – 3.0	p<0.05

* Significance for the difference between the pocket probing depths around implants and teeth.

the mean distance between the inter-implant bone crest and the inter-implant contact point was significantly larger than the mean distance between the bone crest and the contact point between an implant and its adjacent tooth, 5.7±1.6 mm and 3.7±0.7 mm respectively. The mean horizontal distance between two adjacent implants was 3.0±1.3 mm.

Patients rated the aesthetic outcome of their implant crowns in all cases 'acceptable' (mean 8.3±0.8, range 7-10; scale 0-10), while the professionals' judgement, assessed by the implant crown aesthetic index, resulted in 6 'moderate' outcomes and 4 'poor aesthetic' outcomes

Table 4. Frequency distribution of the papilla index scores between two adjacent implants and between an implant and its neighbouring tooth.

	Implant-implant**		**Implant-tooth****	
Score*	N	%	N	%
0	4	40	1	5
1	5	50	5	25
2	0	0	5	25
3	1	10	9	45
4	0	0	0	0
Total	10	100	20	100

* Papilla Index: score 0 = no papilla is present, score 1 = less than half of the papilla is present, score 2 = at least half of the papilla is present, score 3 = the papilla fills up the entire proximal space and is in good harmony with the adjacent papillae, score 4 = the papilla is hyperplastic.

** The Mann-Whitney test showed a significant difference ($p < 0.05$) between the inter-implant papilla and the papilla between an implant and a tooth.

(Table 7). There was no significant correlation between the overall professional satisfaction score by the aesthetic index and the overall patient satisfaction score by the questionnaire. Both the patients and prosthodontist rated the appearance of the mucosa lower than the appearance of the restoration.

Table 6 shows the overall opinions of the professionals and the patients in addition to the papilla index, the distance between the bone crest and the contact point of the implant crowns and the horizontal distance between two adjacent implants. In 1/10 cases the distance between the inter-implant bone crest and the contact point was < 3 mm. The horizontal distance between two adjacent implants was in 5/10 cases > 3 mm.

Discussion

This study reveals that it is difficult to establish predictable and harmonious soft tissues to the professional standards around two adjacent implant crowns placed in an augmented site. The mean pocket probing depth around the implants was deeper than around the neighbouring teeth. This is in accordance with other studies (Bragger et al., 1997). The peri-implant soft tissue health expressed by the bleeding index, the plaque index and the pocket probing depth

Table 5. Mean (SD) and range of bone level values and distance between contact point and the bone crest level at the proximal sides of the implants and the neighbouring teeth (mm).

Location	Mean (SD)	Range	$N_{measured}$/ $N_{available}$	Differences
MBI_i	1.9 (0.4)	1.4 – 3.0	20/ 20	NS*
MBI_t	1.8 (0.5)	0.6 – 2.5	18/ 20	
MBT	-0.7 (0.8)	-1.9 – 0.4	15/ 20	
BC_{i-i}	1.0 (0.7)	-0.5 – 2.0	20/ 20	p<0.05**
BC_{i-t}	-0.8 (0.8)	-2.0 – 0.5	16/ 20	
CP_{i-i}	-4.7 (1.8)	-8.4 – -1.7	20/ 20	NS**
CP_{i-t}	-4.8 (1.4)	-8.1 – -2.6	15/ 20	
$BC_{i-i} – CP_{i-i}$	5.7 (1.6)	2.9 – 7.9	20/ 20	p<0.05**
$BC_{i-t} – CP_{i-t}$	3.7 (0.7)	3.0 – 4.9	12/ 20	
HD_{i-i}	3.0 (1.3)	1.2 – 4.8	10/ 10	

* Differences between proximal sides of the implants facing adjacent implants and facing neighbouring teeth.
** Differences between inter-implant locations and locations between implants and their neighbouring teeth.
Abbreviations: MBI_i and MBI_t = marginal bone level at the proximal sides of the implants facing the adjacent implants and at the proximal sides of the implants facing the neighbouring teeth, MBT = marginal bone level at the proximal sides of the teeth facing the adjacent implant, BC_{i-i} and BC_{i-t} = bone crest level between two adjacent implants and between an implant and its neighbouring teeth. CP_{i-i} and CP_{i-t} = contact point between two adjacent implant crowns and between an implant crowns and the crowns of their neighbouring teeth. HD = Horizontal distance between two adjacent implants, NS = not significant.

showed significant differences between implants and teeth. These results are in accordance with the results of Quirynen et al (2006), that implants with pockets >3 mm showed more bleeding after probing then teeth with shallow pockets (<4 mm).

The results show that a papilla was more frequently present between an implant and its neighbouring tooth than between two adjacent implants. As mentioned in the introduction, features that are thought to affect the presence of a papilla are the distance between the contact point and the bone crest and the inter-implant horizontal distance. Tarnow et al (1992) concluded that in the natural dentition the papilla was always present when the distance between the contact point and the bone crest was ≤ 5 mm. Choquet et al (2001) reported similar observations for single-tooth dental implants. Later studies described that between adjacent implants the ideal distance between the bone crest and the contact point is only 3 mm in order to obtain a complete fill of the proximal space (Tarnow et al., 2003; Gastaldo

Table 6. Scores of the satisfaction questionnaire about the appearance of the restorations, the appearance of the mucosa and the overall appearance of the implants.

Score	Restoration*	Mucosa*	Overall score**
Possible score	0-4	0-4	0-10
Mean (SD)	3.3 (0.6)	2.7 (0.6)	8.3 (0.8)
Range	2.1-4.0	1.8-3.2	7-10
Percentage of acceptable results (2-4)	100%	80%	100%

* Restoration and mucosa sore: scale 0 = completely dissatisfied, 4 = completely satisfied.
** Overall score: scale 0 = completely dissatisfied, 10 = completely satisfied.

et al., 2004). The mean distance between the bone crest and the contact point between two implants in our study was larger than the critical distance of 3 mm described in literature for two adjacent implants (Tarnow et al., 2003; Gastaldo et al., 2004), whereas the mean distance between the bone crest and the contact point between an implant and a tooth was within the critical distance of 5 mm described in literature (Choquet et al., 2001). Our results seem to corroborate the findings of these previous described studies, since the interproximal space was more frequently filled up between an implant and its neighbouring tooth than between two implants.

The distance between the contact point and the bone crest level is highly dependent on the bone crest level. In this study the bone crest level between an implant and its neighbouring tooth seems to be predominantly determined by the marginal bone level of the neighbouring tooth. This is in accordance with other studies (Kan et al., 2003; Grunder et al., 2005). The inter-implant bone crest level was positioned significantly more apically than the bone crest level between an implant and its neighbouring tooth. The inter-implant distance seems to influence the inter-implant bone crest level. Gardaropoli et al (2004) concluded that a reduced inter-implant distance will result in an increased loss in the height of the inter-implant bone crest level. The latter corroborates with the findings of others who reported a lower height of the bone crest and an incomplete regeneration of the papilla when the inter-implant distance was < 3 mm (Tarnow et al., 2000; Gastaldo et al., 2004). In five of our ten cases, the critical inter-implant distance was not met and therefore jeopardizing the inter-implant bone crest level and consequently the complete filling of the proximal space. With the present knowledge, the inter-

Table 7. Scores of the implant crown aesthetic index.

Score	Restoration per implant	Mucosa per implant	Overall score per implant	Overall score per patient*
Possible score	0-25	0-20	0-45	0-45
Mean (sd)	0.9 (0.8)	3.5 (3.0)	4.4 (3.1)	5.5 (3.4)
Range	0-2	1-11	1-11	3-11
Percentage of acceptable results (0-4)	100%	75%	70%	60%

Frequency distribution Overall Score per patient*	N	%
Excellent (score 0)	0	0
Satisfactory (score 1-2)	0	0
Moderate (score 3-4)	6	60
Poor aesthetics (score 5 and higher)	4	40

* For the overall score per patient the implant with the lowest score was used.

implant horizontal distance should be at least 3 mm. Therefore, we would like to pose that when there is not enough space to meet these restrictions, it is preferable to place one implant with an implant-supported restoration with a cantilever, instead of two implant crowns. Another factor which determined the inter-implant bone crest level was the bone crest level at the moment of insertion of the implants. This study group consisted of merely augmented patients who started out with a compromised bone condition. At time of implant placement, the bone crest level between two adjacent implants was at most equal, but not uncommon already positioned more apically than the marginal bone level of the adjacent teeth.

When we combine the two features described in literature, the inter-implant horizontal distance and the distance between the contact point and the bone crest, none of our cases fulfilled both criteria (Table 6). Our results seem to corroborate with the findings of prior literature because in only one case a papilla did regenerate. But this exception also demonstrates that although the criteria were not fulfilled, it was possible to obtain a complete fill of the proximal space. Probably other factors, such as oral hygiene or other patient related factors also influence the final result.

Table 8. Results per patient of the distance between the inter-implant bone crest and the contact point of the implant crowns (mm) and the horizontal distance (mm), the Papilla Index between two adjacent implants, the professionals' and the patients' opinion.

Patient Nr.	BC_{i-i}-CP_{i-i}	HD_{i-i}	Papilla Index*	Professionals' Opinion**	Patients' opinion‡
1	7.4	4.1	0	Moderate	8
2	5.3	1.6	1	Moderate	7
3	5.2	4.1	1	Moderate	8
4	6.3	3.4	0	Poor	8
5	7.9	4.1	1	Poor	8
6	2.9	2.4	0	Poor	8
7	3.6	1.6	1	Moderate	10
8	6.8	4.8	3	Moderate	8
9	4.8	2.4	1	Moderate	9
10	6.5	1.2	0	Poor	9

* Papilla Index: score 0 = no papilla is present, score 1 = less than half of the papilla is present, score 2 = at least half of the papilla is present, score 3 = the papilla fills up the entire proximal space and is in good harmony with the adjacent papillae, score 4 = the papilla is hyperplastic.
** Professionals' opinion; possible scores = excellent, satisfactory, moderate or poor.
‡ Patients' opinion (range 0-10); 0 = very dissatisfied, 10 = very satisfied.
Abbreviations: BC_{i-i}-CP_{i-i} = distance between the inter-implant bone crest and the contact point of the implant crowns, HD_{i-i} = horizontal distance between two adjacent implants.

The aesthetics of many cases were not acceptable according to the opinion of the professionals, while the patients rated all cases as acceptable. This difference in opinion is in accordance with other studies assessing single tooth replacements (Chang et al., 1999; Vermylen et al., 2003; Palmer et al., 2007). Moreover, professionals and patients were less satisfied with the appearance of the mucosa then with the appearance of the implant crown. An explanation of the low aesthetic index score of the mucosa could be that all cases had to be reconstructed by an augmentation procedure prior to implant placement. Therefore, the mucosa had to undergo several traumatic surgeries (Meijndert et al., 2007). Furthermore, as mentioned before, the inter-implant papilla, an item which is judged by the aesthetic index, filled up the entire approximal space in only one case.

Although the opinion of the professional with regard to the aesthetic outcome scores was

very moderate, the patients were satisfied. There was no correlation between the results of the aesthetic index and the opinion of the patients, and the presence of the inter-implant papilla seemed to be of no influence on the opinion of the patient. A reason why the patients appreciated their aesthetics could be that they were informed of the consequences and risks of implant placement prior to treatment and accepted the limitations of the treatment. Additionally, in comparison to the condition of their dentition prior to treatment, the final result was probably very satisfactory to the patients' opinion, and factors often considered by professionals to be of significance for the aesthetic result of restorative therapy may not be of decisive importance for patient satisfaction (Chang et al., 1999).

In conclusion, the results of this study reveal that it is difficult to establish predictable and harmonious soft tissues to the professional standards around two adjacent implant crowns in patients who had been subjected to an augmentation procedure before implant placement. When the recommendations currently described in the literature of the two critical features, viz. the horizontal distance and the distance between the bone crest and the contact point, are not met the complete filling of the proximal space between two adjacent implants should not be expected. Future prospective randomized studies should reveal whether fulfilling these restrictions will provide more predictive results and which other factors might be of influence on the aesthetic result.

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Chapter 5

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